# Pinna cue-preserving hearing-aid fittings: Who might be a candidate?

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## Introduction

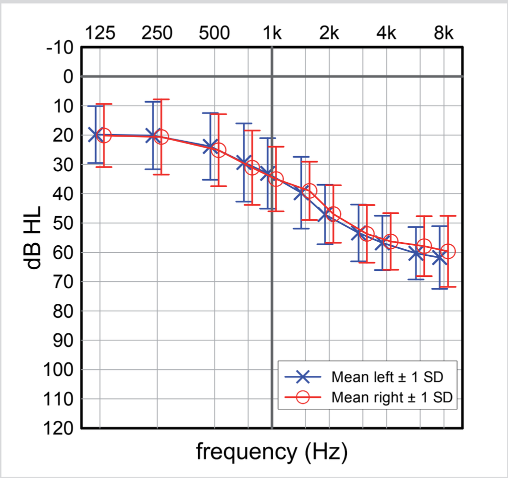
In a companion presentation at this conference, Neher et al. present data from a field test, which investigated the benefits obtainable from preserving pinna cues in hearing-aid fittings.

Test subjects recruited for the field test should ideally have sufficient spatial hearing abilities to be able to show a possible benefit from pinna cue-preserving hearing aids in spatially complex listening situations.

In a preceding phase, presented in this poster, candidate test subjects for the field test were identified based on their performance in two complex listening tests conducted with open ears in the free field. In this candidature-phase, it was also investigated whether basic measures of auditory and cognitive function can be used to predict the ability to utilise pinna cues as measured in the complex listening tests.

## Experimental conditions

### TEST SUBJECTS




- N=31 (one excluded from analysis)
- 42-78 years (mean 65 years)
- Mild-to-moderate, sensorineural, gently sloping, symmetric hearing losses
- Experienced hearing-aid users

### SPATIAL UNMASKING (SU) TEST

Three qualitatively similar female speakers, one target (T) and two maskers (M), uttering Dantale II sentences (e.g., "Michael had five yellow houses"). The task is to repeat the sentence beginning with a given call-sign (e.g., "Michael").

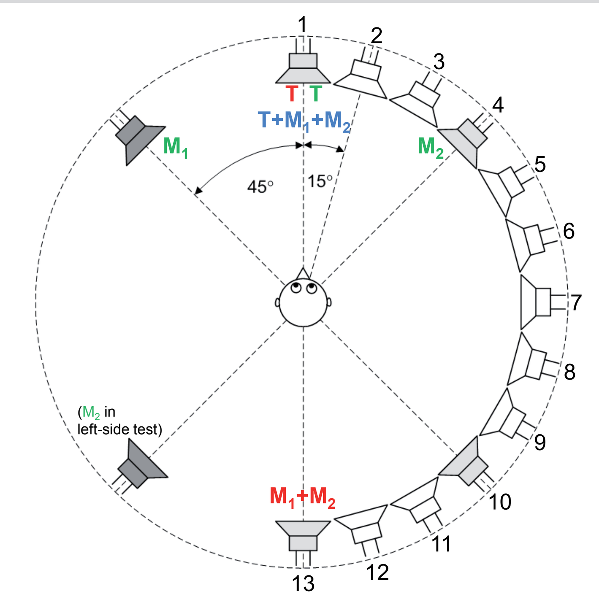
Three anechoic test conditions were included: Co-located (Co-loc), Front-Back (F-B), and Left-Right (L-R).

Speech reception threshold (SRT), indicating 50% intelligibility, was determined for each condition.

SU was calculated as follows:

$SU_{F\text{-}B} = SRT_{Co\text{-}loc} - SRT_{F\text{-}B}$

$SU_{L\text{-}R} = SRT_{Co\text{-}loc} - SRT_{L\text{-}R}$




*Loudspeaker setup used for the two complex tests: The SU test and the localisation test.*

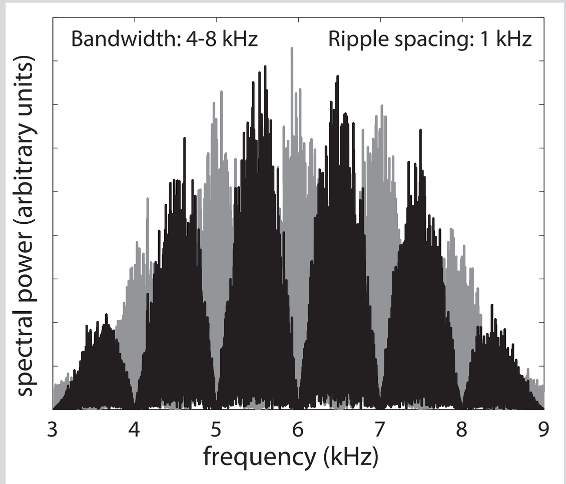
## Experimental conditions, contd.

### LOCALISATION TEST

- 13 loudspeakers positioned in an anechoic room on the side of the test subject's better ear (as determined by the SRD test, see below).
- Sound stimulus was a train of four 300-ms noise bursts, bandpass filtered to 4-8 kHz. Level roving was applied. Following a stimulus, the subject's task was to indicate the number of the relevant loudspeaker (1-13) on a touch screen.
- Localisation error measures: Mean and RMS errors in the F-B and L-R dimensions (cf. Good & Gilkey, 1996), and percent F-B errors.

### SPECTRAL RIPPLE DISCRIMINATION (SRD) TEST

- Meant to quantify the ability to detect changes in monaural spectral shape (as those introduced by pinna filtering). Test paradigm developed by Supin et al. (1994).
- Measures ripple spacing needed to discriminate between 4-8 kHz bandpass filtered noise spectra with flipped and constant ripples.
- Stimuli presented via headphones. Both ears were tested. Results from better ear used in analysis.




*Example of stimuli spectra in the SRD test. In the target interval, the black and grey spectra alternated every 0.5 secs, whereas only one of the two spectra was presented in the reference intervals.*

- Adaptive 3I-3AFC procedure coupled with a one-up-two-down staircase rule, tracking the 70.7% correct point on the psychometric function.

### ENSURING AUDIBILITY

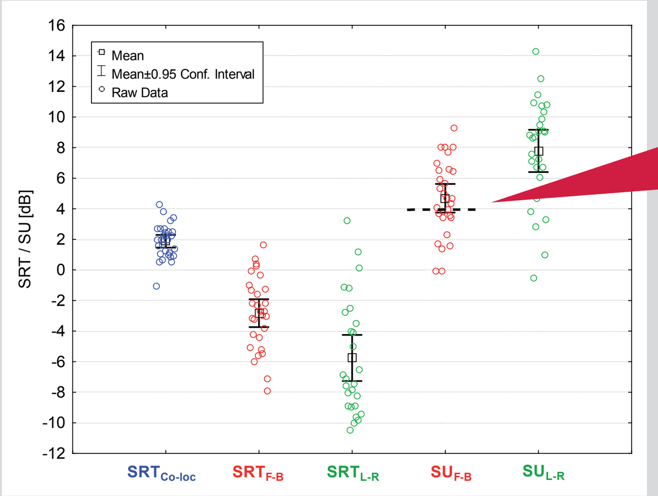
All auditory tests were carried out unaided. A companion poster by Laugesen et al. presents the special considerations, which were made to make the various acoutic stimuli sufficiently audible.

### COGNITIVE TESTS

- Reading Span test (probes into working memory)
- Test of Everyday Attention (TEA). Two subtests included.
  - Map Search (probes into selective attention)
  - Visual Elevator (probes into switching attention)

## Results

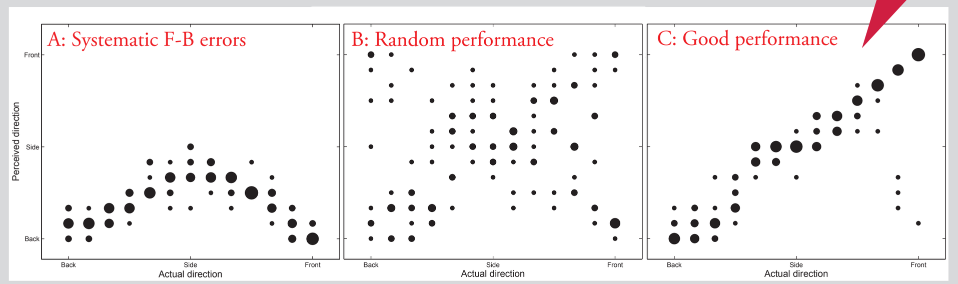
### SPATIAL UNMASKING DATA




**Candidacy for the subsequent field test of pinna cue-preserving hearing aids required $SU_{F\text{-}B} \geq 4$ dB (spatial unmasking should exceed SRT benefit caused by pinna shadow effect, which is 3 dB according to Freyman et al., 2005).**

**Candidates for the field test should show localisation performance at a level indicating that they could be disadvantaged by pinna-cue removal.**

### LOCALISATION DATA (examples)




| | A | B | C |
|---|---|---|---|
| F-B mean error (deg) | 49 | 3 | 5 |
| F-B RMS error (deg) | 79 | 68 | 25 |
| F-B error % | 50 | 44 | 4 |

### INTER-CORRELATIONS OF COGNITIVE PREDICTORS

*The correlation coefficients reported in this and the following sections are based on either parametric (Pearson) or non-parametric (Spearman) statistics, depending on whether the observations of the included variables were normally distributed or not (as determined by a Shapiro-Wilk's W test).*

| | Age | Reading Span | Map Search | Vis. Elevator |
|---|---|---|---|---|
| Age | 1 | - | - | - |
| Reading Span | -0.33 | 1 | - | - |
| Map Search | -0.53** | 0.28 | 1 | - |
| Vis. Elevator | -0.19 | 0.19 | 0.03 | 1 |

**No significant correlation between age and Reading Span / Visual Elevator – this is not according to expectations.**

### INTER-CORRELATIONS OF MONAURAL PREDICTORS

| | Age | $3FAHL_{high\_best}$ | SRD |
|---|---|---|---|
| Age | 1 | - | - |
| $3FAHL_{high\_best}$ | 0.32 | 1 | - |
| SRD | 0.48** | 0.12 | 1 |

**Assuming that SRD is related to frequency selectivity, a significant correlation with HF hearing loss was expected.**

### PREDICTION OF FRONT-BACK COMPLEX MEASURES

| | Age | $3FAHL_{high\_best}$ | SRD | Reading Span | Map Search | Vis. Elevator |
|---|---|---|---|---|---|---|
| F-B mean error | 0.00 | 0.02 | 0.27 | -0.01 | -0.10 | 0.23 |
| F-B RMS error | 0.11 | -0.10 | 0.10 | -0.31 | -0.35 | -0.09 |
| F-B error % | 0.20 | -0.04 | 0.12 | -0.34 | -0.35 | -0.04 |
| $SRT_{F\text{-}B}$ | 0.01 | 0.08 | -0.11 | -0.17 | 0.14 | -0.45* |
| $SU_{F\text{-}B}$ | 0.04 | 0.03 | 0.17 | 0.17 | -0.18 | 0.26 |

- With one exception, there are no significant correlations between the chosen predictor variables and the complex F-B test measures.
- SRD does not seem to tap into the skills required for the F-B listening tasks.
- Absense of cognitive correlations may be due to an unrepresentative test-subject group in terms of cognition (cf. no significant correlation between Reading Span and age).

## What about the L-R dimension?

The focus of this study was performance in the front-back dimensions of the complex listening tests where pinna cues play an important role. However, performance in the L-R dimensions was investigated as well, and it was also investigated whether this performance could be predicted by relevant basic auditory and cognitive measures.

A binaural test, $IPD_{BW}$, was performed to obtain an estimate of the effective bandwidth of binaural temporal fine structure (TFS) processing, assuming that this measure could have predictive power on performance in the L-R dimension.

| | Age | $4FAHL_{low}$ | $3FAHL_{high\_best}$ | $IPD_{BW}$ | Reading span | Map search | Vis. Elevator |
|---|---|---|---|---|---|---|---|
| L-R mean error | -0.18 | 0.11 | -0.12 | -0.12 | 0.08 | -0.07 | -0.27 |
| L-R RMS error | 0.15 | -0.13 | 0.34 | 0.15 | -0.07 | -0.31 | 0.28 |
| $SRT_{L\text{-}R}$ | 0.36 | 0.46* | 0.25 | -0.35 | -0.36 | -0.30 | -0.51** |
| $SU_{L\text{-}R}$ | -0.37 | -0.43* | -0.12 | 0.51** | 0.40* | 0.26 | 0.45* |

- Several significant correlations emerge for the $SRT_{L\text{-}R}$ and $SU_{L\text{-}R}$ data, including correlations with LF hearing loss, $IPD_{BW}$, Reading Span, and Visual Elevator. This is in good agreement with findings in a previous study (Neher et al., 2009).
- No significant correlations emerge for the L-R localisation data.

## Conclusions

- Out of 30 test subjects completing all tests, 20 subjects showed performance in the front-back dimensions of the complex localisation and spatial-unmasking tests, which made them qualify as test subjects in the field test of pinna cue-preserving hearing aids.
- The performance in the front-back dimensions of the complex listening tests could not be predicted by the basic auditory and cognitive measures included in the study.
- Performance in the left-right dimension of the spatial-unmasking test correlated significantly with several auditory and cognitive measures, most of which had previously been found to have predictive power.

## References

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- Good & Gilkey (1996), "Sound localization in noise: The effect of signal-to-noise ratio," J Acoust Soc Am, 99(2), 1108-1117.
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- Supin et al. (1994), "Frequency resolving power measured by rippled noise," Hear Res, 78, 31-40.

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